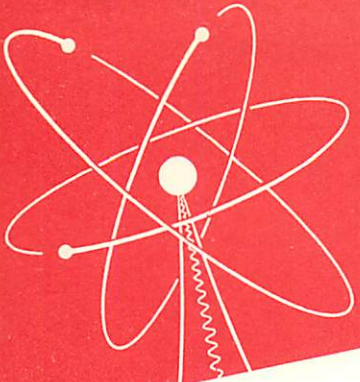

ANTENNAS

Lesson T2C-18A

DeVRY Technical Institute
4141 W. Belmont Ave., Chicago 41, Illinois
Formerly DeFOREST'S TRAINING, INC.

T2C-18A

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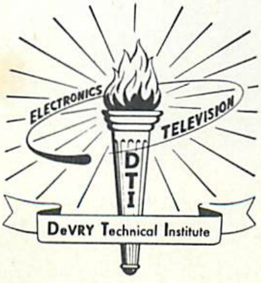

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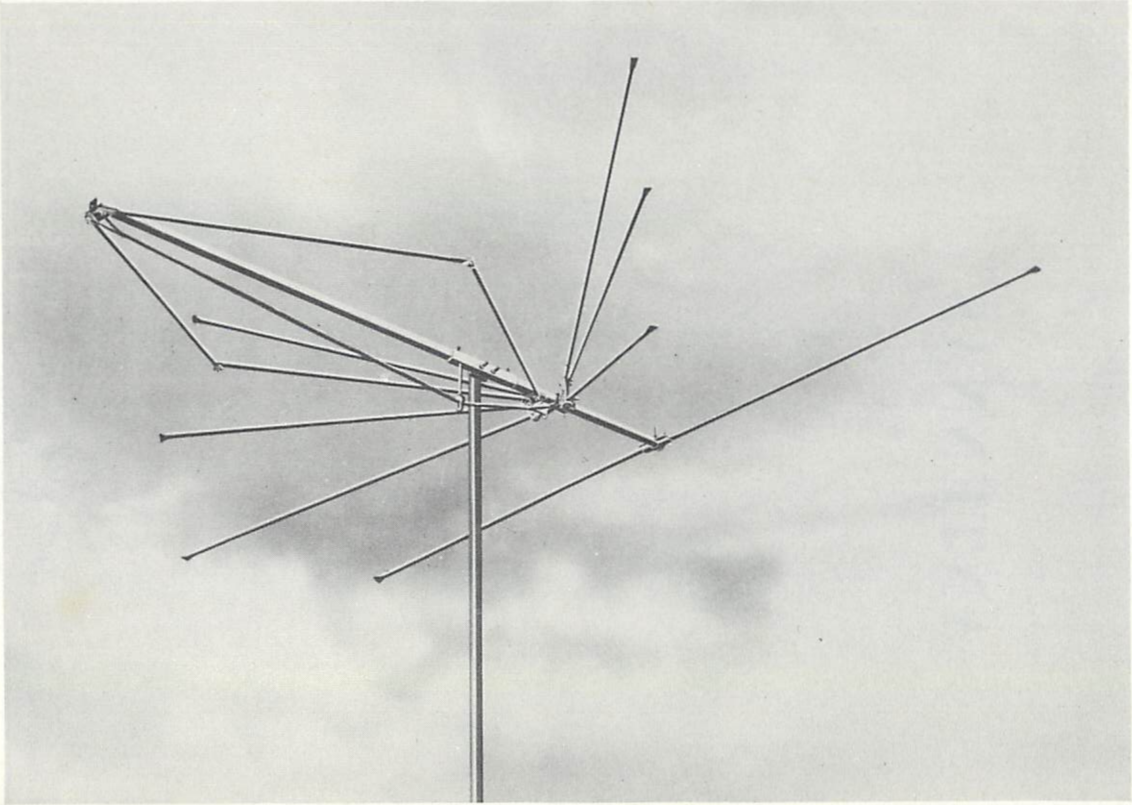

As described in this lesson, the unit shown is a combination of two types of antennas: the rhombic for UHF reception, and the conical-V with reflector for VHF reception.

Courtesy JFD Mfg. Co., Inc.

ANTENNAS

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While we must indeed face the future with a clear view of its possible perils, we need not quail before it.
—Dexter Perkins

ANTENNAS

WHY TELEVISION ANTENNAS ARE NEEDED

Due to the nature of television transmission, a good antenna system is much more important for television reception than for the reception of standard AM broadcast radio waves. The wide band of frequencies required for television transmission has made it necessary to use carrier waves which are located in the VERY HIGH FREQUENCY (VHF) and ULTRA HIGH FREQUENCY (UHF) regions of the frequency spectrum. Five channels of the VHF television band extend from 54 to 88 megacycles, while seven channels cover the region from 174 to 216 megacycles. The remaining seventy channels are in the UHF region and extend from 470 to 890 mc.

At these VHF and UHF frequencies, transmission and reception are on a line-of-sight basis, which means that intervening buildings or other objects may obstruct the path of the carrier waves and thus impair reception. Other factors directly affecting reception quality are the strength of the desired signal relative to that of any interfering signals or noise energy at the receiver location, and the fact that multiple images, known as GHOSTS, may be produced if the desired carrier wave is reflected from the sides of buildings or other objects. Because of their high frequencies these television carriers act much like light waves, and such reflection is a common occurrence.

Thus, at any particular receiver location, the signal strength and relative freedom from reflected waves and interference are the principal factors determining the type of antenna system which will provide satisfactory reception. Generally speaking, the electric characteristics or specifications of the receiver make or model are considerably less important.

Although many television receiver manufacturers advertise satisfactory reception with an antenna which is built into the receiver cabinet, the majority favor an external antenna, and preferably one which is installed at a high elevation out-of-doors. Because of the many factors which can interfere with television reception, the built-in type of antenna is restricted to the rather small number of receiver locations in which ideal reception conditions exist.

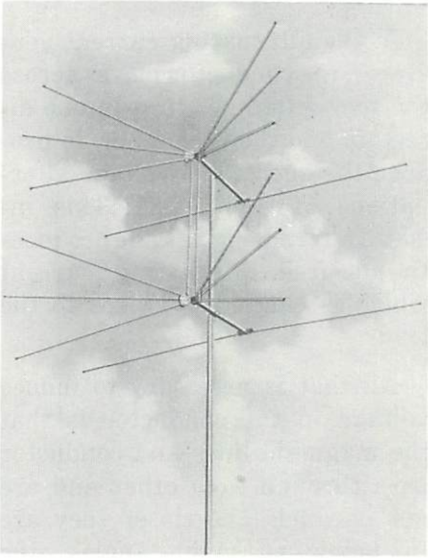
For example, objects such as metal conduit, water pipes, metal venetian blinds, and metal used in the construction of the building may have a shielding effect or cause reflections, so that it is desirable to locate the antenna at some point other than that most suitable for the receiver. Many times an improvement can be obtained by employing an indoor-type antenna situated at some other point in the room, in another room, or in the attic. However, the height at which the antenna is mounted is an important factor in overcoming these various difficulties. This is especially true for UHF. Therefore, in many cases, an outdoor antenna is the only type which can be installed high enough to clear certain obstructions or be far enough away from local sources of interference to provide a good quality of reception.

ANTENNA REQUIREMENTS

In an earlier lesson, we explained that the FCC has adopted a set of television transmission standards with which all stations must comply. One standard that is particularly related to the receiving antenna states: "It shall be standard in television broadcasting to radiate horizontally polarized waves."

A radio wave consists of electric and magnetic components that are at right angles to each other. The direction of the electric component is considered the polarization of the entire wave. The wave is emitted from a transmitting antenna with its electric component parallel to the plane of the antenna. Thus, a transmitting antenna must be horizontal if it is to radiate horizontally polarized waves.

To receive maximum energy from the radio wave, the polarization of the receiving antenna should be the same as that of the wave. Therefore, television receiving antennas are mounted in a horizontal position. In addition, the antenna must possess the necessary characteristics to provide adequate signal strength to the receiver input. This assumes, of course, that there is sufficient field strength at the antenna, because beyond a certain distance from the transmitter, the field intensity



Conical type antennas with reflectors, mounted as a broadside array.

Courtesy JFD Mfg. Co., Inc.

is too low for reception with the best possible antenna.

As explained in an early lesson, when a conductor moves or cuts through a magnetic field an electric voltage is induced in the conductor. The direction of the voltage is determined by the direction in which the lines are cut.

In the alternating current generator, the conductor moves across the magnetic lines first in one direction and then the other, to produce the successive voltage alternations of each cycle. This induced alternating voltage produces the desired alternating current which is carried by wires to the load.

All that is necessary to induce voltage in the conductor is that the magnetic lines and conductor pass through each other and are not parallel. The closer they are to being at right angles, the greater the induced voltage. The greater the speed of cutting, the greater the induced voltage. Also, the longer the conductor, the greater induced voltage. It makes no difference whether a conductor moves through a stationary magnetic field, or a stationary conductor is cut by a moving field. In either case, a voltage is induced in the conductor.

Basically, a receiving antenna is merely a conductor suspended in space. Radiated from the transmitting antenna, the radio wave strikes and passes through the receiving antenna. With the electric component of the wave parallel to the axis of the antenna, the magnetic lines of force cut the conductor at right angles, as they pass through it, to induce a voltage. Thus, so far as the receiver is concerned, THE ANTENNA IS A GENERATOR. The alternating magnetic field component of the received r-f wave cuts the antenna conductor to induce an alternating voltage. In turn, the induced voltage produces an alternating current which forms the signal carried by the transmission line to the receiver input.

In ideal locations, a very simple antenna is satisfactory, but since the vast majority of locations are far from ideal insofar as field intensity and interference are concerned, more complex antennas have been developed. Various elements have been added and certain modifications have been made until some of the modern antennas have assumed fairly elaborate shapes.

In addition to good electric characteristics, the antenna must possess satisfactory mechanical characteristics. It must be strong enough so that it will not be bent out of shape by the wind or by the added weight of a coating of ice and snow. It must be of a material that resists corrosion. In many installations, it is desirable that the antenna be constructed of a light material. Aluminum is a very popular metal for this use since it is light in weight and corrodes very little compared with many other metals. The mast and other supporting sections often are made of steel tubing which is coated to prevent corrosion.

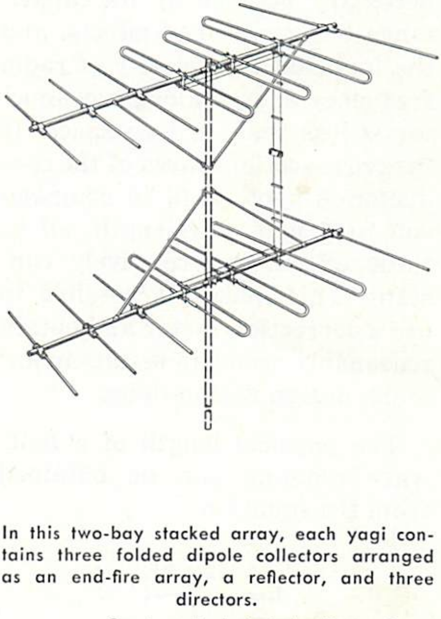
THE HALF-WAVE DIPOLE ANTENNA

Like a transmission line, an antenna has distributed inductance, capacitance, and resistance, therefore it resonates at some frequency. When a straight wire is suspended in space, its resonant frequency has a wavelength approximately equal to twice that of the wire, and, when used to intercept r-f energy, a wire of this type is known as a half-wave antenna.

At resonance, the voltage and current distribution on this antenna are as shown in Figure 1. Indicated by the broken line curve, the current is minimum at the ends but rises to maximum at the center while the solid line curve shows the voltage is maximum at the ends and minimum at the center.

Referring to Figure 2, a practical antenna of this type consists of two lengths of conductor, placed end to end, with the inner ends connected to a transmission line, which, in turn, is attached to the receiver input. Connected in this manner, the antenna is called a **dipole.**

Radio energy travels through space in the form of waves, each one of which is equivalent to one electric cycle. As the velocity of all radiated radio energy is the same, in the form of a general equation, the relationship between wavelength and frequency is:



In this two-bay stacked array, each yagi contains three folded dipole collectors arranged as an end-fire array, a reflector, and three directors.

Courtesy Technical Appliance Corp.

$$\text{Wavelength (meters)} = \frac{300}{\text{Frequency (megacycles)}}$$

and as 300 meters equal 984.25 feet, the equation can be changed to:

$$\text{Wavelength (feet)} = \frac{984}{\text{Frequency (megacycles)}}.$$

Physically, the length of the halfwave dipole is made slightly less than one-half wave. This is necessary because of its capacitance to ground, end effects, and the fact that the velocity of radio frequency energy along a conductor is less than in free space. If the cross-sectional area of the conductor is kept small in comparison to a half wavelength, all of these effects are relatively constant. This makes it possible to use a correction factor and obtain reasonably accurate results in antenna design calculations.

The physical length of a half-wave antenna can be obtained from the equation:

$$L = \frac{492 \times .94}{f},$$

where:

L = length in feet

f = frequency in megacycles

492 = a constant

.94 = correction factor for frequencies above 30 mc.

As an example, assume that it is necessary to determine the physical length of a television antenna that is to operate at a frequency of 69 megacycles. Substituting 69 for f in the equation, the dipole length may be computed by:

$$L = \frac{492 \times .94}{69} = 6.7 \text{ ft.,}$$

or 6 ft. 8½ in. (approx.)

This is the total length from one end of the antenna to the other, including the spacing between the inner ends to which the transmission line is connected.

As mentioned previously, the half-wave antenna acts like a series resonant circuit, delivering maximum output at the frequency to which it resonates. However, at all other frequencies the output is less than at resonance. This fact must be considered in antenna design and a resonant frequency chosen so the response over the desired band is satisfactory.

As a compromise, the frequency used should be the geometric center frequency of the desired band, and may be obtained from:

$$f_g = \sqrt{f_a \times f_b},$$

where:

f_g = geometric center frequency

f_a and f_b = the desired frequency range limits.

For example, assume that the desired frequency range is from 54 mc to 88 mc, then:

$$f_g = \sqrt{54 \times 88} = \sqrt{4752} = 69 \text{ mc.}$$

Thus, 69 mc is the frequency that should be used when computing the physical length of a dipole antenna which is to be used over the frequency range of 54 to 88 mc. The length of the dipole is 6.7 ft., as indicated previously.

ANTENNA CHARACTERISTICS

Every antenna has three important characteristics or qualities which determine its performance. These qualities should be understood by the technician so that he can intelligently choose the proper antenna for any given reception condition. Antenna development engineers employ various means of controlling these qualities when designing a unit which will operate in a particular manner over a desired frequency band.

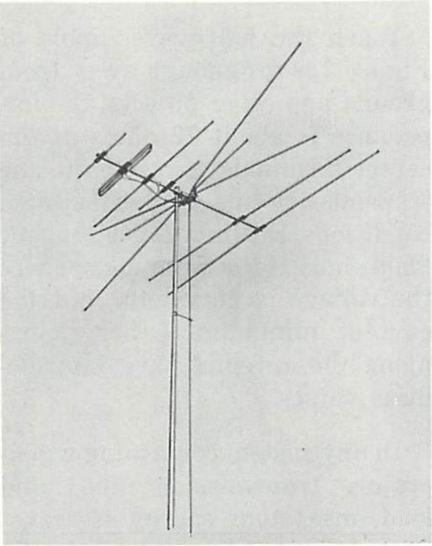
Impedance

It has been mentioned that an antenna has the electrical properties of inductance, capacitance, and resistance. These properties cause the antenna to act like a series resonant circuit. At any point along the antenna, the impedance is equal to the ratio of the r-f voltage to the r-f current at that point. That is, $Z = E/I$. In the case of the half-wave dipole, the voltage is maximum at the ends, and minimum at the center as shown in Figure 1. The current is minimum at the ends and maximum at the center. Therefore, the impedance is highest at the outer ends, and lowest at the center. However, the impedance is not a fixed quality. It varies with frequency, height of the antenna above ground, and its nearness to other objects and antennas.

When the half-wave dipole of Figure 2 is far enough away from ground and other objects, the impedance is about 72 ohms at the center terminals connected to the transmission line. Under the same conditions, the impedance is about 2500 ohms at the outer ends where the voltage is maximum, but the current minimum. Other points along the antenna have intermediate values.

In any system containing a generator, transmission line, and load, maximum energy is transmitted from the generator to the load when the generator impedance matches the line and the line matches the load. In Figure 2, the antenna is the generator and the receiver is the load. Therefore, the transmission line should have a characteristic impedance equal to the input impedance of the receiver. Also, the antenna impedance should be equal to that of the line.

As explained, the impedance varies along the antenna, from minimum at the center to maximum at the outer ends. In practice, however, when an antenna is said to have some certain value of impedance, we are speaking of its impedance at the point where it connects to the transmission line. This is the point at which the antenna impedance should be the same as the line impedance.



A three-conductor folded dipole with parasitic elements employed in conjunction with a conical antenna and its corresponding parasitic elements.

Courtesy JFD Mfg. Co., Inc.

Some receivers have 72 ohm input impedances. In these cases, perfect matching is obtained with a 72-ohm transmission line and a simple half-wave dipole antenna like that of Figure 2. However, in most installations, a 300-ohm receiver and line are matched by a more complex type of antenna which has a center impedance in the neighborhood of 300 ohms.

It has been stated that an antenna is like a series resonant circuit. Because of this fact, its impedance is exactly equal to the rated value only at the frequency at which the antenna is one-half wavelength long. Above and below this frequency, the antenna impedance changes at a rate depending upon the Q. When the antenna has high Q, its impedance falls off rapidly either side of the resonant frequency. This type of antenna delivers sufficient signal to the transmission line over a narrow band of frequencies only. On the other hand, a wide-band antenna is one in which the impedance falls off gradually above and below resonance due to its low Q. Thus, the ability of an antenna to maintain a fairly constant impedance as frequency changes actually is a measure of its bandwidth. Whether a given antenna has low or high Q depends upon the specific application for which it has been designed.

Directivity

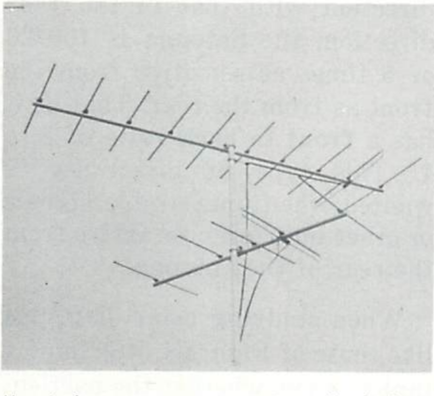
The **directivity** of a television receiving antenna is a measure of its ability to receive signals from desired directions compared with its rejection of signals from undesired directions. Information of this type is given in the form of what is known as a polar diagram. Figure 3A is the polar diagram of a half-wave dipole like that of Figure 2. This diagram represents the directivity as seen looking down from above the antenna, with the antenna in a horizontal position. In Figure 3A, a heavy line drawn on the 90°-270° axis represents the dipole, and the loops show that this antenna receives best at right angles to its axis. In the direction of its axis, its response is nearly zero. For purposes of reference, we can consider the top of the graph, 0°, the front of the antenna, and the 180° direction the back of the antenna. Thus, the simple dipole receives as well from the back as from the front.

In the polar diagrams, the curves or loops are more accurately called LOBES. For simplicity, usually the lobes are drawn so that the maximum response is set at 100. This does not mean 100 microvolts, or 100 of any other unit. It is merely a convenient way of indicating the ability of the antenna to receive signals from various directions compared with its ability in the direction of maximum reception. For example, at the point where the curve crosses the circle marked 50, it indicates the angle at which the antenna is 50% as sensitive as it is head on at 0°. But it does not indicate how many microvolts the antenna provides to the transmission line, nor does it give any information regarding the sensitivity of the antenna compared with other antennas.

A somewhat more complex antenna than that of Figure 2 has directivity as shown by the curves in the polar diagram of Figure 3B. Here, the antenna is not drawn on the graph, but is assumed to occupy the same position as that of Figure 3A. Again, the major lobe extends in the 0° direction to the circle marked 100, indicating the sensitivity at the front. The relative response to signals arriving from the back is represented by the small lobe which extends as far as the circle marked 20. Thus, comparing the antenna pickup ability in the 0° direction with that in the 180° direction, the antenna is 100/20 or 5 times as sensitive from the front as from the rear. That is, it has a **front to back ratio** of 5 to 1. This type of directivity is wanted when undesirable signals or other interferences arrive from the rear of the antenna.

When studying polar diagrams like those of Figure 3, it is important to know whether the particular graphs indicate voltage ratios or power ratios. Either type is correct technically. The important point is, all diagrams compared should show the same type of ratio. If a graph showing a voltage ratio is compared with one showing a power ratio, the results are misleading. The reason is that power is equivalent to the square of the voltage.

For example, assume the polar diagram of Figure 3B represents a voltage ratio of 5 to 1. With signals of equal strength arriving at the front and back, the antenna delivers to the receiver 5 volts of the signal coming from the front for every 1 volt of the signal coming from the back. These voltage values squared give the power ratio. Thus, $5^2 = 25$, and $1^2 = 1$, for a power ratio of 25 to 1. The polar diagram of Figure 3C shows a front to back ratio of 25 to 1. Therefore, the diagrams of Figures 3B and 3C represent the voltage and power ratios, respectively, of the same antenna, or of two antennas with like directivity.



Mounted on a common mast, each of these highly directive, single channel yagis points toward the station from which it is designed to receive signals.

Courtesy Technical Appliance Corp.

The misleading part is the difference in the sizes of the small lobes in Figures 3B and 3C. If, at first glance, it is assumed that both diagrams represent voltage ratios, for instance, it appears that the graph of Figure 3C indicates much greater directivity than that of Figure 3B. Of course, this is not so. As explained above, any antenna that has a front to back voltage ratio of 5 to 1 has the same directivity as one which has a front to back power ratio of 25 to 1.

Another important point to bear in mind regarding directivity patterns is that each polar diagram like those of Figure 3 represents the conditions at one particular frequency only. A given antenna may have excellent directivity on one channel, but very poor directivity on another. In some cases, there may be a large difference between the front and back ratio for the picture and sound carriers of the same channel. Therefore, when evaluating the performance of an antenna, polar diagrams at several frequencies over the band should be considered.

Gain

Antennas can be compared with regard to their ability to receive a signal. The measure of this ability is called the **gain** of an antenna. Although various methods can be used, the commonly accepted way employed by most reliable manufacturers is to compare the signal voltage provided by an antenna with that provided by a half-wave dipole at each particular frequency under consideration. The unit of measurement used to make this comparison is the DECIBEL, abbreviated "db". An antenna is stated as having a gain of so many db at a given frequency.

The decibel is not a fixed quantity like a volt, ohm, or ampere. It is a definite ratio between two quantities. Thus, one "pair" of compared quantities may both be much larger than a second pair. However, if the ratio of the larger to the smaller in one pair is equal to the ratio of the larger to the smaller in the other pair, then, in both cases, the larger is the same number of decibels greater than the smaller. For example, the ratios 100/25 or 4 and 8/2 or 4 are the same.

In the case of antennas, the quantities compared are microvolts. The decibel is a convenient unit for comparing antenna performance. Regardless of what the particular signal strength from a desired station is at a given receiving point, at the center frequency of that channel, an antenna having a rated gain of so many db will provide a signal voltage a corresponding amount greater than that obtained from a dipole designed for the same frequency.

If an antenna is designed to receive in one certain channel, then its gain in decibels is determined by comparing its output with that of a dipole one-half wavelength long at the center frequency of that same channel. In the case of a broadband antenna, its gain for each channel is determined separately by comparing it with a series of half-wave dipoles, one cut for the center frequency of each channel which the broadband antenna has been designed to receive.

When comparing high band and low band performance of antennas, an important point to bear in mind is the fact that the induced signal voltage varies directly with the length of the antenna. In the drawing of Figure 4, assume the dot at the center represents the location of a television broadcast station. Assume also that at a certain distance, the radiated signal induces 5000 microvolts in a wire one meter in length. At that point, we say the signal strength is equal to 5000 microvolts per meter. This is abbreviated as 5000 μv/m.

Since the station radiates the carrier in all directions, we can find many more locations at which the same signal strength exists by moving in a circle around the station. If we draw a map and connect these points with a line, the line is a circle with the station at its center. If we move away from the station to where the signal strength is 1000 μv/m, and then to where it is only 100 μv/m, each time repeating the process, our map is like the drawing of Figure 4.

Suppose two stations, one operating on channel 2 and the other on channel 13, are located at the center of an area represented by the drawing, and that they are transmitting with exactly the same power. In this case, the circles represent the field strengths of both stations. Thus, at any point on the 100 μv/m circle, a wire one meter long has 100 microvolts induced in it by the signal from each of the two stations. A dipole antenna designed for the center frequency of channel 2, is approximately two meters in length. Therefore, located at the 100 μv/m line, this antenna has approximately 200 microvolts induced in it. On the other hand, a dipole cut for channel 13 is only about one-half meter in length. Located at the same distance from the transmitter, this antenna has only about 50 microvolts induced in it. That is, a channel 2 dipole picks up approximately four times as much signal as a channel 13 dipole.

Because of this difference, if a broadband antenna has a gain of 5 db, for example, in both channels 2 and 13, then this antenna provides considerably less signal voltage to the lead-in for channel 13 than it does for channel 2. Therefore if it is desired to apply the same voltage to the lead-in for high band stations as for low band stations, the broadband antenna should have a much greater db gain at the high band frequencies than it does at the low band frequencies. In practice, broadband antennas are designed to achieve these results.

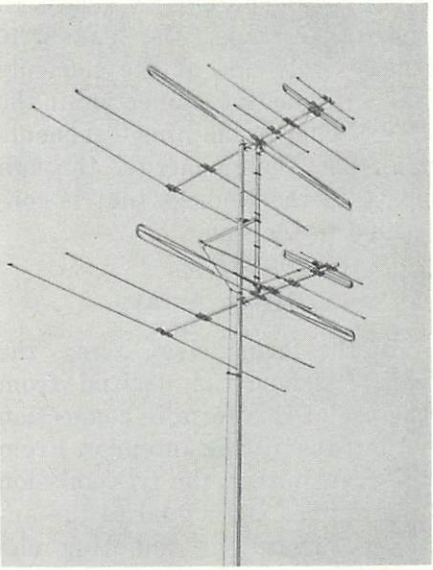
ANTENNA ARRAYS

Television antennas are designed in a large variety of sizes and shapes. One reason for this variation is the never ending efforts of engineers to develop units of improved characteristics. Another is the many different reception conditions which exist. At some receiving locations, the desired signals arrive from several directions, and the antenna then should not be one which receives from a single direction only. In other cases, a more or less highly directional unit may be needed to receive the desirable signals which are coming from one general direction, but reject undesired signals arriving from other directions.

A relatively simple high Q antenna can be employed when only one channel is to be received. If several channels, widely spaced in frequency, are to be received, a broad band antenna system is needed. Where the receiving location is a great distance from the transmitting stations, the signals are relatively weak. The receiver is said to be located in a FRINGE AREA, and requires a high gain antenna. If one or more sources of interference exist in the neighborhood of the receiver, the antenna should have directivity characteristics such that it receives well from the horizontal direction but rejects r-f energy coming from beneath it. This type of directivity, along with high gain, is especially important in fringe areas.

Since some of these receiving conditions require antenna characteristics which are the exact opposite of those required by other conditions, it is not possible to design a single antenna which satisfies all needs. Antenna manufacturers provide different types, each specifically designed to fulfill a particular reception condition.

Antennas are composed of parts or components called ELEMENTS. The dipole of Figure 2 is a single element unit consisting of two quarter-wave rods end to end, with their inner ends connected to the transmission line. The point on the element at which the signal is fed to the transmission line is called the FEED POINT. Thus, the arrangement of Figure 2 is known as the CENTER FEED system. As mentioned, the half-wave dipole antenna has an impedance of about 72 ohms, relatively low "signal gathering" ability, and receives equally from all directions at right angles to its axis. To obtain a particular desired performance, this basic element is modified in form, other elements are added, or both.



Designed for VHF all-channel reception, two identical units are mounted to form a stacked array to increase gain and decrease pickup from above and below.

Courtesy JFD Mfg. Co., Inc.

When an antenna contains more than one element, the unit is called an **array.** Antenna arrays are of two general classes, according to the method employed to transfer the energy from the various elements to the transmission line. When a conductive connection is made between each element and the line, the arrangement is called a DRIVEN ARRAY. In the other type, the PARASITIC ARRAY, only one of the elements has a conductive connection to the line. The remaining elements transfer their energy through space to the element that is connected to the line.

Driven Arrays

In the term driven array, the word "driven" is derived from the use of this term in connection with transmitting antennas. From the transmitter, the transmission line applies the signal to the antenna. Thus, the radiating element is "driven" by the signal. However, in the case of the receiving antenna, the antenna elements provide the driving signal which is carried by the transmission line to the receiver. Antennas that use driven elements are of two types, the BROADSIDE ARRAYS, and the END-FIRE arrays.

In a broadside array, two or more elements are arranged such that, when their induced currents are in the same direction, the currents are combined in phase in the transmission line. A two-element broadside array is shown in Figure 5A. Two half-wave dipoles are mounted one above the other in a vertical plane and have their feed points connected together. The transmission line is connected midway between them so the currents fed to the line are in the same phase.

Figure 5B is a view looking at the ends of the dipoles. The horizontal oval represents the directivity pattern obtained. As the transmitter is at the same distance from both dipoles, its signal arrives at both elements at the same instant, therefore the element currents combine in phase. However, signals coming from below or above the antenna arrive at one element sooner than at the other. At any given instant, the current fed to the transmission line from one element is out of phase with that fed from the other element. This overall action increases the pickup in the desired horizontal directions, but reduces pickup of noises and ground reflected signals from below the antenna, and airplane reflected signals from above.

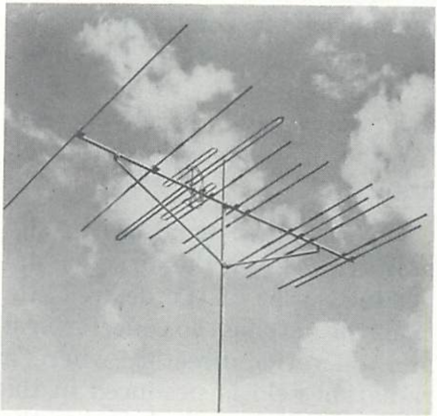
In an end-fire array, the elements are arranged so that, when their induced currents are in the same direction, the currents are combined 180° out of phase in the transmission line. Figure 6A shows a two-element end-fire array. The elements are mounted horizontally at the same height, one behind the other. The leads from the two dipoles are connected to the transmission line. However, as shown, before connecting to the line, the leads from one dipole are transposed.

A view looking at the ends of the dipoles is shown in Figure 6B. In the case of undesired signals or noise arriving from above or below the antenna of Figure 6A, the energy reaches both dipoles at the same time to produce in phase element currents. The transposed leads cause these currents to be fed exactly 180° out of phase to the transmission line. The result is complete cancellation, so that the line carries no undesired signal or noise current. This action is indicated by the directional pattern of Figure 6B.

Since the dipoles are at unequal distances from the transmitter, one dipole receives the desired signal later than the other. Thus, at any given instant, the desired signal wave is at a different phase at the front dipole than that which it has at the rear dipole. As a result, the currents fed to the transmission line are not 180° out of phase, but have in phase components which add to increase the gain of the system over that of a single element antenna.

Parasitic Arrays

In a parasitic array, two or more elements are mounted, one in front of the other, at the same height, on the same plan as the end-fire driven array. Only one element is connected to the transmission line, while the others, called the parasitic elements, are merely "space coupled" to this connected element. The element connected to the line is called either the COLLECTOR or the driven element. The latter name is borrowed from transmitter terminology, and actually infers the opposite action to that which occurs at the receiving antenna.



Providing reception on all VHF channels, this yagi type antenna employs a tri-pole type collector, and an individual set of parasitic elements for the respective high and low bands.
Courtesy Channel Master Corp.

Known as a DIRECTOR, the parasitic element of Figure 7 is placed in front of the collector. The arrows indicate the direction from which the desired signals are arriving. The director is slightly shorter than the collector, so that its resonant frequency is higher than that of the collector. Therefore, the director has capacitive reactance at the frequency to which the collector is resonant.

Arriving from the transmitter, the signal wave strikes the director first and induces a voltage that lags the signal field by 90°. Since the director is capacitive at the signal frequency, the director current leads the induced voltage by 90°, and therefore, it is in phase with the signal field. Due to this current, the director radiates an electromagnetic field, thus functioning as a second transmitter. As the radiation from the director is in phase with the signal field, the two add, thereby increasing the field strength at the collector.

On the other hand, when signals arrive from the direction opposite to that of the desired station, they strike the collector first and then the director, where a radiation field is produced in the manner just described. Due to the order in which the elements are cut by the signals, the field radiated by the director reaches the collector out of phase with the signal field. With this phase relationship, the fields oppose each other and thereby reduce the voltage induced in the collector. Thus, the director increases the collector sensitivity to signals from the desired direction and reduces its sensitivity to signals from the opposite direction.

In Figure 8, the parasitic element is slightly longer than the collector, and is placed on the side opposite the desired transmitter. In this position it is known as a REFLECTOR. Its greater length causes it to be resonant at a frequency lower than that of the collector. Due to its lower resonant frequency, the reflector is inductive at the frequency to which the collector is tuned.

With this arrangement, the r-f wave from the desired station strikes the collector first, then, an instant later, the reflector. Induced by the r-f field, the voltage in the reflector lags behind that in the collector by an angle that is determined by the spacing between the two elements. In the reflector the induced voltage lags the r-f field by 90° and the resulting inductive current lags by another 90°. In phase with the current, a field is radiated from the reflector and, because of the spacing between them, the portion of this radiation arriving at the collector is nearly in phase with the r-f wave from the transmitter, thus increasing the field strength at the collector.

When a signal is received from the opposite direction, the r-f wave strikes the reflector first and induces into it a voltage that lags the field by 90°. The resulting current lags the induced voltage by another 90° and is, therefore, 180° out of phase with the r-f wave. In phase with the current, the field radiated by the reflector is 180° out of phase with the r-f wave, and they tend to cancel each other, thus greatly reducing the sensitivity of the antenna to the undesired signal.

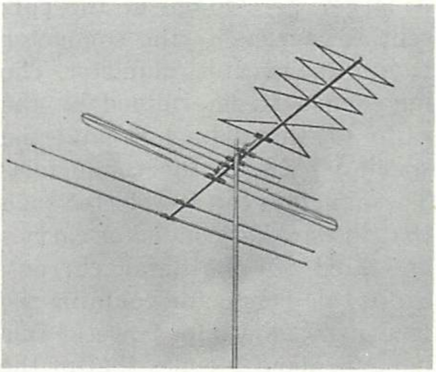
TELEVISION RECEIVING ANTENNAS

In areas where more than one station is received, the antenna must be capable of operating over a broader frequency band than that covered by the simple dipole. Also, it is desirable that the television receiving antenna have an impedance in the neighborhood of 300 ohms, to provide a better match to the 300-ohm transmission lines commonly employed.

Folded Dipoles

One modification of the dipole is that shown in Figure 9A. Called a FOLDED DIPOLE, this unit consists of two closely spaced conductors connected together at the outer ends. However, because of the impedance changing characteristics of the folded dipole, the feed point impedance is four times as great as that of the straight dipole. Consequently, the folded dipole of Figure 9A has an impedance of 4×72, or 288 ohms. For practical purposes, this impedance is considered to be about 300 ohms, and permits the antenna to match the 300-ohm line.

When directors or reflectors are added to any antenna to form a parasitic array, the antenna impedance decreases. The reduction varies directly with the nearness of the parasitic elements to the collector. Therefore, it is desirable that a folded dipole have more than 300-ohms impedance when it is to be used in such an array. Then, when the parasitic elements are added, the impedance falls to around 300 ohms.



Another all-channel VHF antenna. This unit has a folded dipole with parasitic elements for low band reception. For high band channels, both the dipole and the helix section contribute signal pick up.

Courtesy JFD Mfg. Co., Inc.

Shown in Figure 9B, a three conductor folded dipole, compared to the simple dipole of Figure 2, provides an impedance changing characteristic such that its impedance is 9 times that of the straight dipole. Hence, the antenna of Figure 9B has an impedance of 9×72, or 648 ohms. Connected in parallel, two such antennas have an equivalent impedance of 324 ohms to provide a practical match to a 300-ohm line.

A second method of increasing the folded dipole impedance is to employ two conductors of unequal diameters as shown in Figure 9C. A larger percentage of the current is carried by the conductor having the greatest diameter. The impedance is determined by the ratio of the diameters and the spacing between the conductors. These factors can be selected such that the smaller conductor carries one-third of the total current. Since this conductor contains the feed point, the impedance at this point is about 9 times that of the straight dipole, or approximately 600 ohms.

The relationship between the inductance, diameter, and Q of an antenna is such that an increase in diameter results in a decrease in inductance. This change of inductance reduces the Q, since Q is equal to X_L/R. The lower the Q, the wider the frequency band over which the impedance remains fairly constant. Therefore, a wide band antenna is one which has low Q.

The folded dipoles of Figure 9 are electrically equivalent to a single conductor of large diameter. Consequently, these antennas have low Q and a wide frequency response. This characteristic makes them more desirable than the straight dipole when signals from several stations are to be received. When antenna gain measurements are made, the reference dipole type employed is the 300-ohm folded dipole of Figure 9A, rather than the straight dipole of Figure 2.

Conical

A second construction method employed to increase the conductor diameter and lower the Q is illustrated in Figure 10. Known as a CONICAL ANTENNA, this unit consists of two cone shaped conductors with their apexes at the feed point. The entire element is approximately three-quarters of a wavelength long. The large diameter of the cones results in a very low Q, such that the basic form of Figure 10 maintains its impedance substantially constant over a frequency ratio of about 4 to 1. For example, this ratio corresponds to the VHF carrier range of 54 to 216 mc. That is, 216:54 =4:1.

The solid cone of Figure 10 has the physical disadvantage of high resistance to wind, especially when its dimensions are those required for operation in the VHF bands. Due to this fact, commercial antennas are modified conicals, and have the forms shown in Figure 11. These antennas are also called V antennas and fan antennas.

However, their operation is basically that of the conical because of the mutual coupling between the rods of each section. Two rods are employed in place of each cone in the antenna of Figure 11A, while each cone is represented by three rods in the version shown in Figure 11B.

The unit of Figure 11C contains two rods for each cone or V section like that of Figure 11A, but in Figure 11C, the outer ends of the rods are tilted forward toward the transmitter. This arrangement makes the antenna more sensitive to signals arriving from the front than to those arriving from the back, and also more closely resembles the true conical antenna.

In the UHF band, the shorter wavelengths permit antennas to be of smaller dimensions. The wind resistance of the antenna is of less importance, and the fan or simulated conical antennas can consist of solid triangular sheets, as shown in Figure 11D. Because of its appearance, this design is known as the bow tie antenna.

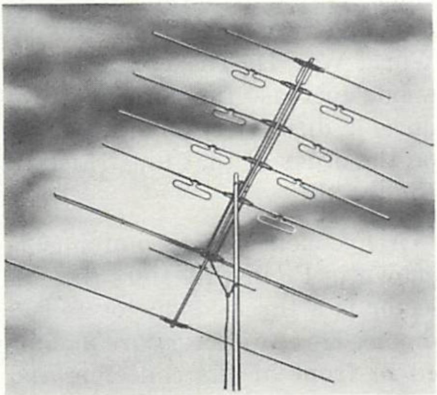
The units of Figure 11 do not have quite as low Q's as the true conical of Figure 10. However, with additional elements, they can be made to cover a frequency ratio of about 3 to 1. With this response, an antenna of this type can cover most of the VHF channels, or all of the UHF band, the limits of which are 470 to 890 mc, a ratio of less than 2 to 1.

Yagi

An array containing two or more parasitic elements is called a YAGI ANTENNA. The name of this device is derived from the fact that the arrangement was developed by the Japanese physicist, Hidetsugu Yagi. This antenna, incidently, found widespread use as a mobile radar antenna during World War II. The parasitic elements increase the gain and produce a directivity characteristic on the order of that illustrated in Figure 3B.

A five-element yagi antenna is shown in Figure 12. Here the collector is a three-conductor folded dipole. Three directors are mounted in front of the collector, and one reflector behind it. As in this example, usually only one reflector is used. The reason for this is that, after the first, additional reflectors do not increase the gain to any great extent. However, a worthwhile gain increase is obtained with each added director.

Besides increasing gain and directivity each additional parasitic element reduces the impedance of the antenna, as mentioned previously. As the distance between the parasitic element and the collector increases, less and less coupling occurs between them. After the third director, the coupling is too little to effect the impedance by any great extent. However, the directivity still increases, and yagis are constructed with as many as 10, 15, or 20 elements. Although it has excellent gain and directivity, a simple yagi like that of Figure 12 has very high Q, and therefore a narrow bandwidth which permits operation usually on a single channel only.



Broadband yagi antenna. The small folded dipoles are phasing elements employed to provide in phase currents from all three sections of each long element to the transmission line.

Courtesy Technical Appliance Corp.

Long Wire V

As explained for Figure 4, at a given distance from the transmitter, the voltage induced in an antenna varies directly with the length of the element. Thus, more signal voltage is developed in an antenna which is several half-wavelengths long than in a half-wave element. This fact is employed to increase the antenna sensitivity over that of the half-wave types. Antennas which are two or more half-wavelengths long are called LONG WIRE ANTENNAS.

For example, an antenna which is one half-wavelength long at 60 mc is three half-wavelengths long at 180 mc. At 60 mc, its polar diagram is like that of Figure 3A. Furthermore, at 180 mc, the third harmonic of 60 mc, its current distribution is as shown in Figure 13A. The antenna acts like three half-wave elements connected end to end, with the current in the middle section 180° out of phase with the currents in the two end sections. Due to these current phase conditions, the maximum pick up is in the directions indicated by the major lobes in the pattern of Figure 13B, instead of at right angles to the axis of the element.

If a single long wire element were employed for wide band reception, it would be necessary to shift its position when different stations were desired, due to its changing directivity pattern. This action is made unnecessary by connecting two long wire elements in the form of a "V", as shown in Figure 13C. The V angle is selected such that the major pickup lobes coincide at the highest operating frequency to be used. At lower frequencies, the lobes shift so that they are not in the same direction, and the directivity is impaired to some degree. However, the V ANTENNA is still directional even at ⅓ the highest operating frequency. Thus, the V antenna provides good directivity over a frequency ratio of about 3 to 1. The impedance of this type of unit remains constant to provide a substantial gain over a frequency ratio of about 2 to 1.

Rhombic

A second type of long wire antenna is the RHOMBIC ANTENNA, shown in Figure 14. This device is an extended version of the long wire V, and over which it has several advantages. For one, the rhombic has a high front to back ratio, and thus does not receive signals from the rear. The rhombic has gain equivalent to that obtained by two V elements. Also, the rhombic has less sensitivity to signals arriving from above and below the antenna. Finally, its impedance remains constant to maintain its gain over a wide frequency range.

As shown in the Figure, the rhombic antenna is a diamond shaped arrangement, with the feed point located at the junction of two of the "legs". At the other end of the antenna, in the Figure, an arrow indicates the direction from which signals are received with maximum sensitivity. Both the rhombic of Figure 14 and the V antenna of Figure 13 have the disadvantage of relatively large physical dimensions at the VHF range, but are small enough for practical application in the UHF band.

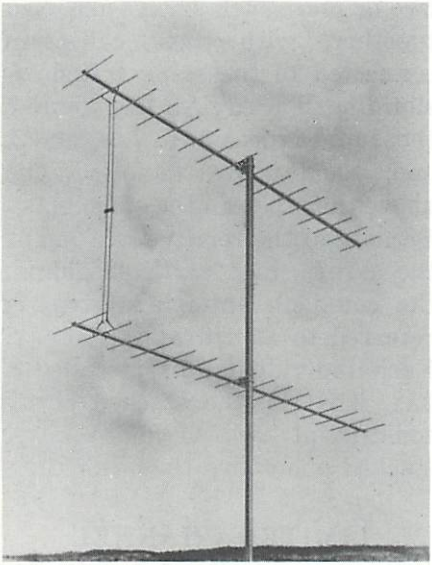
STACKED ARRAYS

Where receiving conditions require even greater gain or directivity than can be obtained from a given parasitic or driven array, two or more such arrays are used together, with their collectors connected to the same transmission line. The arrays may be like those of Figures 5, 6, 7, 8, or 12, and usually are mounted one above the other on the same mast. Because of the relative location of the arrays, in a vertical column, the complete antenna system is referred to as a STACKED ARRAY. Each individual unit is called a BAY. That is, the stacked array consists of two or more bays, stacked one above the other.

LIMITED CHANNEL ANTENNAS

When reception of a single channel, or a few channels not widely separated in frequency is desired, the high Q type of antennas are employed. These include the simple straight dipole of Figure 2, and the driven and parasitic arrays of Figures 5 through 8. When greater gain is needed, more elements, either parasitic or driven may be added to these basic structures, or these units may be combined to form stacked arrays. Even greater gain and directivity are obtained by means of the yagi, either singly, as in Figure 12, or in the form of a stacked array.

As an example, Figure 15 shows a typical commercial antenna of the type employed for high gain and directivity on a single channel. The unit consists of two ten-element yagis forming a stacked array which provides a voltage gain of about 13½ db relative to a folded dipole designed for the same channel.



A UHF antenna consisting of two 16-element yagis in a stacked array.
Courtesy Channel Master Corp.

MULTI-CHANNEL ANTENNAS

As explained for parasitic arrays, antenna elements can be spaced some given fraction of a wavelength apart so that the arriving signal has a different phase at each element. Likewise, if the signal is carried through a length of transmission line a fraction of a wavelength long, its phase is different at the end of the line than at the input terminals. These fractions of wavelengths can be designated in degrees for convenience. Thus, a line one wavelength long is also 360° long, a line one-quarter wavelength long is 90° long, a one-eighth wave line is 45° long, and so on. Antenna elements can be spaced 45° apart, 90° apart, 30° apart, and so on, depending upon the desired characteristics.

Use is made of these facts in connecting more than one collector to a single transmission line so that the desired signals arriving at the line aid rather than cancel each other. The sections of line employed to provide the desired phase relationships make up what is known as an INTERCONNECTING HARNESS.

An example of these phasing arrangements is a broad band yagi developed by the Channel Master Corporation. This antenna incorporates two folded dipole collectors, one tuned to a frequency near the high end and the other to a frequency near the low end of the VHF low band. The method employed to obtain the desired directivity is illustrated in Figure 16. As indicated, the dipoles are 45° from each other in space, and connected with a harness which is 135° long. The terminals of the large dipole form the feed point for the transmission line in this simplified illustration.

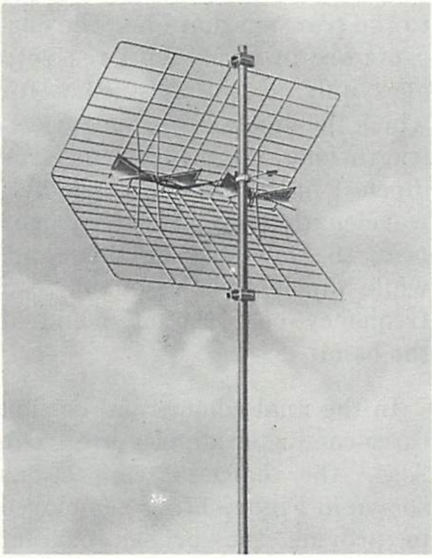
A signal arriving from direction A, the back of the antenna, cuts dipole 2 45° later than it hits dipole 1. From dipole 2, this signal is fed back through the 135° length of line to the feed point. Therefore, travelling in space from dipole 1 to dipole 2, and then back through the line to dipole 1, the signal picked up by dipole 2 lags that at dipole 1 by a total of 45° + 135°, or 180°. Thus, signals arriving from the back of the antenna induce dipole currents which cancel at the feed point.

On the other hand, a signal coming from direction B, at the front of the antenna, cuts dipole 2 45° earlier than dipole 1. The signal induced in dipole 2 is delayed 135° in traveling through the harness to the feed point. Since this signal originally led by 45°, it has a net lag of 135° − 45°, or 90° at the feed point, with reference to the signal induced in dipole 1. Although 90° out of phase, these two signals add to provide a total of 1.4 times the signal that would be fed to the line by a single folded dipole used alone.

Although the arriving carrier waves induce voltages in the antenna elements, these voltages produce currents which are fed to the transmission line. The currents are in phase with the voltages only at the frequency for which the dipole is one-half wavelength long. As mentioned, large dipole 1 in this system is one-half wavelength long at a frequency near the low end of the band, while dipole 2 is resonant to a frequency near the high end of the band.

In the final commercial design, three-conductor dipoles are used. Also, the harness connections shown in Figure 17, are employed to provide the proper current phasing at the feed point. Here, dipole 1 connects to the feed point through a 15° length of harness line, while dipole 2 connects through a transposed line 45° long. When a signal to which dipole 2 is resonant arrives from the front of the antenna, the voltage induced produces an in phase current in the small dipole. When it arrives at the feed point, this current lags by 45° due to the length of the harness line, and an additional 180° due to the fact that the line conductors are transposed. The total lag of dipole 2 current is therefore 45° + 180°, or 225° at the feed point.

This same carrier wave travels a distance of 45° through space to cut dipole 1. Since the large dipole is resonant at a lower frequency, it offers inductive reactance to the higher frequency signal. In an inductive circuit, the current can lag the voltage up to 90°. In this system, the antenna is designed so that the current lags the induced voltage by 75°. Another 15° lag is added by the harness connection to the feed point. Thus, with respect to the voltage induced in dipole 1, the current supplied by dipole 2 to the feed point lags by a total of 45° + 75° + 15°, or 135°. Since the current from dipole 1 lags by 225°, the currents fed from the two dipoles to the transmission line have a phase difference of 225° − 135°, or 90°, as mentioned with regard to Figure 16. This arrangement then provides a total signal greater than that obtained by a single dipole.



Two bow tie elements, side by side, with a corner reflector for UHF reception.

Courtesy JFD Mfg. Co., Inc.

Referring again to Figure 17, when a signal to which dipole 2 is resonant arrives from the rear of the antenna, the voltage induced in the small dipole produces a current which, as before, lags by 225° when it arrives at the feed point. The current induced in dipole 1 lags the voltage by 75°, and the harness adds another 15° lag for a total of 90°. However, the signal cuts this dipole 45° earlier than dipole 2. Therefore, the net lag of the dipole 1 current at the feed point is 90° − 45°, or 45°. As a result, the dipole currents have a phase difference of 225° − 45°, or 180° to produce cancellation at the feed point.

In the case of a signal to which the large dipole is resonant, the small dipole is capacitive and the current produced leads the induced voltage by 75°. The transposed harness line introduces a lag of 225°, so that the current has a net lag of 225° − 75°, or 150° at the feed point. Compared with its arrival at dipole 2, the signal cuts dipole 1 45° later. This element is resonant at the signal frequency, therefore the induced voltage produces an in phase current. The harness line adds a 15° lag to provide a total lag of 45° + 15°, or 60° for the dipole 1 current at the feed point. Thus, the dipole currents, when fed to the transmission line, have a phase difference of 150° − 60°, or 90°.

Finally, arriving from the rear of the antenna, a signal to which dipole 1 is resonant produces an in phase current in this element, and this current lags by 15° when it reaches the feed point. The signal arrives at dipole 2 45° later, and induces a voltage which produces a 75° leading current. The harness provides a lag of 225°, so that compared with the signal arrival at dipole 1, the dipole 2 current has a net lag of 45° − 75° + 225°, or 195°. Thus, the dipole currents have a phase difference of 195° − 15°, or 180° at the feed point.

Like phase conditions are produced for signal frequencies throughout the range over which this dipole system is designed to operate. Shown in Figure 18, the completed yagi includes a reflector and several directors to increase the gain and directivity. This antenna is produced in various models which cover from three to five channels in the low VHF band, or all seven channels in the high band.

VHF ALL-CHANNEL ANTENNAS

Due to the large ratio of 4 to 1 between the upper and lower frequency limits of the VHF range, the design of a single antenna with high uniform gain and good front to back ratio over all 12 channels is rather difficult. As a result, antenna engineers have devised a variety of methods of obtaining the desired performance.

One type of antenna designed for reception on all VHF channels is shown in Figure 19. Called an IN LINE antenna, this unit consists of two folded dipoles and a reflector. For signal frequencies in the high band, the small folded dipole acts as the collector, and the large dipole as a reflector. On the low band channels, the large folded dipole serves as the collector, and the small dipole as a director. The third element serves as a reflector for all 12 channels. For greater signal strength, this antenna is stacked as shown in Figure 20.

A common method of securing pickup of all 12 VHF channels with a single antenna system is to employ collector and parasitic elements which are one-half wave long at a frequency in the low band, and modifying the structure so that each element acts like three separate half-wave elements at the third harmonic of this frequency. For example, if the dipole of Figure 21 is one half-wavelength at 67 mc, it is also $1\frac{1}{2}$ wavelengths, or three half-wavelengths, at 201 mc. Since 67 mc is near the low end of the low band, and 201 mc near the high end of the high band, this dipole serves as a half-wave antenna for the low band channels, and as a one and one-half wave antenna for the channels in the high band. When an antenna receives signals at a harmonic frequency in this way, it is called a COLLINEAR ARRAY (end to end array) of half-wave elements.

However, the basic form shown in Figure 21A does not provide the desired gain and directivity at frequencies at and near the third harmonic of its fundamental. For the low band frequencies, the dashed line in Figure 21A shows the current distribution. The figure eight curve is the directivity desired for all channels. As mentioned with regard to long line antennas, the current distribution and the directivity are as shown in Figure 21B for the high band frequencies. Here, the cloverleaf directivity pattern is due to the fact that, in the center section of the element, the current has the opposite direction of that in the end sections.

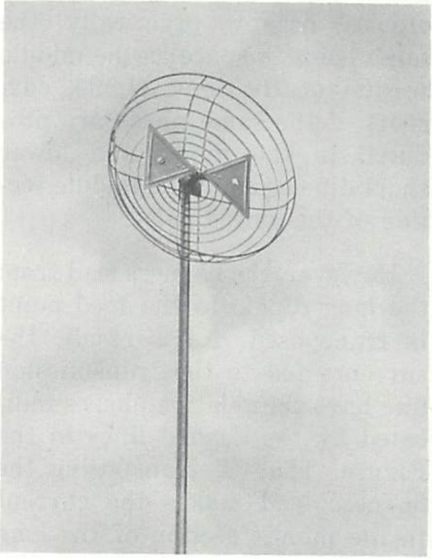
The desired action is illustrated in Figure 21C. The element is broken up into three dipoles, side by side, each one-half wavelength long at the high band frequencies. As indicated, all currents are in phase. Fed to the transmission line, these in-phase currents add to increase the gain and produce the required directivity indicated. To obtain this desired action with the single long dipole of Figure 21B, some method must be employed to counteract the undesirable effect of the middle section out-of-phase current.

One method consists of connecting the three half-wavelength sections through parallel resonant LC circuits. In Figure 22A, the small V elements or whiskers illustrate a practical application of this system. The distributed inductance and capacitance of the whiskers resonate at a frequency in the high band, and act like a parallel resonant circuit. At the low band frequencies, the whiskers are too short to have any effect, and the unit operates as a single long dipole. At the high band frequencies, current is reversed in phase as it passes from one section to another, thus providing the in-phase relationships indicated. However, the high impedance of the whisker elements at and near resonance opposes current passing from one section of the dipole to another. The result is that the long dipole is practically cut off to a half wavelength electrically at the high band frequencies, with considerable reduction in gain.

A second method employed is that of tilting the ends of the long dipole forward as shown in Figure 22B. As explained for the long wire V type antenna, this procedure makes the forward lobes of the cloverleaf pattern coincide for high band operation. A disadvantage of this construction, for all-channel operation, is that on the low band, only about three-quarters of the dipole length is effective as a capturing device.

Three dipole sections can be connected with shorted, quarter-wave sections of transmission line as shown in Figure 22C. Known as a MATCHING STUB, each quarter-wave line may be considered an additional half-wave section of antenna, which is folded back on itself to cancel its pickup. Thus, the entire unit is equivalent to an antenna element five half-wavelengths long, with the current in each stub having the phase of that of the middle section of the long element of Figure 21B. Therefore, the arrangement of Figure 22C causes the currents to be in phase in the three sections of the antenna. However, a quarter-wave shorted line acts like a parallel resonant circuit in that it has high impedance across its input terminals. Consequently, at and near resonance, the stubs limit the current which can pass from one section to another. This condition is a limiting factor on the gain that can be obtained.

Except at the resonant frequency, the quarter-wave stub has only reactance, either inductive or capacitive. A much lower Q can be obtained by use of an antenna element, the impedance of which is made up of both reactance and resistance. Connected in place of the stubs of Figure 22C, low Q elements such as folded dipoles provide the desired phase reversing action as indicated by the current distribution curves in Figure 22D. The low impedance of the dipoles reduces the blocking effects of the matching stub arrangement, and the dipoles increase the signal capturing area of the antenna.



With bow tie collector, this UHF antenna employs a dish shaped reflecting screen similar to those used with radar antennas.

Courtesy JFD Mfg. Co., Inc.

A fifth method devised to feed in-phase currents to the transmission line at high band channel frequencies is illustrated in Figure 22E. Here, two high band dipoles are added to the long dipole, and all three connected to the transmission line. Since the added dipoles occupy practically the same point in space as the middle section of the long dipole, currents of the same phase are produced in the upper and lower short dipoles as in the middle section of the long dipole.

However, the harness lead from the long dipole to the feed point is transposed. As a result, the currents fed to the transmission line have the relative phases indicated by the dashed lines in the Figure. That is, transposing the harness lead makes the current in the middle section of the long dipoles 180° out of phase with those in the short dipoles. Consequently, the short dipoles and the end sections of the long dipole have in-phase currents. The current of one short dipole cancels that of the middle section of the long dipole. The current of the other short dipole fills in the "gap" left by the cancelled currents so that the overall effect is like the desired conditions described for Figure 21C.

A yagi antenna designed for reception of all 12 VHF channels is shown in Figure 23. This unit consists of a collector, two directors, and two reflectors. For the high band channels, the collector and the nearest director operate as colinear arrays which employ the phase reversing method of Figure 22D. To add its energy in phase at all frequencies, this director is connected by a transmission line to the collector, rather than parasitically. The second director is split into two sections which are connected by a quarter-wave stub for maximum efficiency in the high band. The reflector nearest the collector consists of three sections, insulated from each other by means of fiberglass. This element is employed for the high band only. The second reflector is a low band reflector, and at high band frequencies acts as a shield against signals from the rear, rather than a parasitic element.

In the high band, the collector, three section reflector, and two directors act as a group of yagi antennas side by side. In the low band, the folded dipoles and shorted stub are too small to have any appreciable electric effect. The two directors, collector, and low band reflector operate as a single yagi. However, the phase reversing elements increase the effective lengths of the antenna elements, and thus increase the impedance of the antenna.

The phase reversing method of Figure 22E is employed in the commercial broad band yagi illustrated in Figures 24 and 25. As shown in Figure 24A, antenna impedance is increased by using folded dipoles instead of straight dipoles. All three folded dipoles are considered as a single element, called a "tri-pole", and employed as the collector in the complete antenna, Figure 25. In the top view of the array, Figure 24B, the tri-pole collector is indicated by the letter "C". All of the other elements in this unit are of the parasitic type. However, an important feature of this design is that completely separate sets of directors and reflector are employed for low and high bands. In Figure 24B, heavier solid lines represent the three directors and one reflector for low band operation. The light lines indicate the high band parasitic elements, each of which consists of three colinear sections insulated from each other. The high band operation of this system is that of three yagi antennas located side by side.

So far as low band operation is concerned, interference between the two systems of elements is not produced by the intermixing in positions because the high band half-wave sections are too short to resonate at low band frequencies. However, the low band elements produce third harmonic resonant currents when cut by the high band carrier waves, as explained for Figure 21B. Energy re-radiated from these elements can have a cancelling effect on that re-radiated from the high band parasitic elements. To prevent this undesired action, it is necessary to employ a particular spacing system such that, on high band operation, the high band elements "rob" most of the incoming signal energy from the low band elements.

To accomplish this desired action, the high band directors are placed quite close to the low band directors. An advantage of the independent sets of parasitic elements for each band is that each element can have a length which provides best operation in the band for which it is designed. That is, compromise element lengths are not required for optimum operation on both bands.

The design of a third commercial VHF all-channel antenna is illustrated in Figures 26 through 29, while the antenna is pictured in Figure 30. The folded dipole collector and the low band parasitic elements are shown in Figure 26. In this design, the total length of the dipole is one-half wavelength at a frequency near the high end of channel 3. A half wavelength long at a channel 2 frequency, the channel 2 reflector extends the response to cover channel 2. Although of a length normally used for channel 3, the channel 3 reflector is actually employed to decrease the collector impedance at higher frequencies. This rod is called a phasing element, the addition of which extends the response up through channel 4. A second phasing element, cut for a channel 5 frequency, is located in front of the collector. Its purpose is to extend the response up through channel 5 and into channel 6.

For the high band frequencies, the antenna employs a group of collectors connected in the crisscross manner shown in Figure 30. This combination is called a helix. Each element of the helix is tuned separately to one high band channel, and thus provides high gain and directivity on that channel. The helix collectors are all connected together, so that their currents are added at the input to the transmission line.

Figure 27 shows the folded dipole, a phasing element, and the first section of the helix. Like the antennas of Figures 23 and 25, the collector dipole is three half-wavelengths long at the high band frequencies. In Figure 27, the dashed lines indicate the relative phase of the currents in the three sections of the dipole and in the helix.

Two devices are employed to reduce the amplitude of the current in the middle section of the dipole. First, this element contains the added strips which run from the ends of the dipole to points along the top and bottom conductors. These added conductive strips permit greater current in the end half-wave sections of the dipole than there is in the middle section, as indicated. Second, located in front of the dipole, the phasing element blocks energy from being received by the middle section of the dipole at high band frequencies.

The arrangement of the complete set of elements is shown in Figure 28. Located between the helix and the blocking element, a second high band element serves as a reflector for the helix. As indicated, the folded dipole terminals form the feed point to which the transmission line is connected. The current phase of the helix is the same as that of the middle section of the dipole, as shown in Figure 27. This helix current should be fed to the transmission line in such manner that its phase is the same as that of the currents in the end sections of the dipole. These desired in phase conditions are provided by inverting the leads of the harness that connects the helix to the feedpoint, as shown in Figure 29.

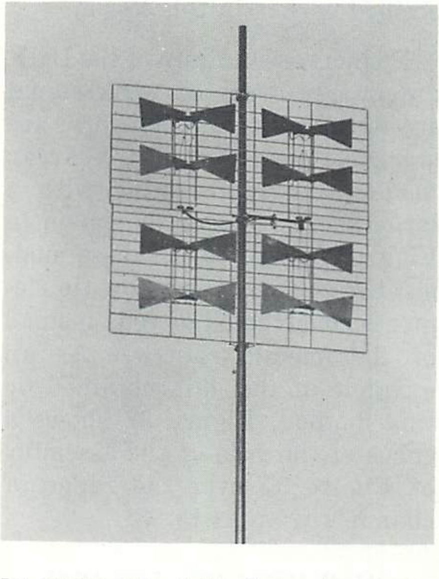
At the low band frequencies, the helix acts only as a shorted stub connected across the terminals of the folded dipole. Its effect is to lower the antenna impedance at the high frequency end of the low band, and thus extend the low band response through the upper end of channel 6.

UHF ALL CHANNEL ANTENNAS

As mentioned earlier, the ratio between the upper and lower limits of the UHF range is only about 2 to 1. Because of this smaller ratio, compared with that of the VHF range, relatively simple antenna structures provide all-channel reception of UHF signals. That is, an antenna design which has narrow or moderate bandwidth at VHF can be employed as a wideband antenna at UHF. Due to the short wavelengths at UHF, a half-wave antenna element has small dimensions, and therefore a relatively small signal voltage is induced in it by the received carrier waves. However, when necessary, the signal collecting ability can be increased by the use of long wire type antennas. These types are more practical for UHF because their physical dimensions are small compared with their VHF counterparts.

Five types of antennas employed for UHF reception are illustrated in Figures 31 through 35. All of these units provide reception of channels 14 through 83, inclusive.

Figure 31 shows the conical type antenna, consisting of a pair of flat, triangular shaped elements. This type of unit is called a "bow-tie", or "fan dipole" antenna. To increase the front to back ratio of the bow tie, a large flat sheet of conductive material, called a SHEET REFLECTOR is used. The sheet reflects the r-f waves in the same manner that light is reflected by a glass mirror. However, a solid metal sheet has too much wind resistance. Therefore, the practical application of this method consists of the rectangular "screen" shown in the Figure.



For greater gain, eight collector elements are employed in this UHF unit, with a screen reflector to provide directivity.

Courtesy Channel Master Corp.

A second form of sheet reflector is shown in Figure 32. Known as a CORNER REFLECTOR, this reflecting screen is designed to concentrate the reflected waves in the direction of the collector element. While increasing the pickup of signals from the front, the sheet and corner reflectors shield the collector from interference from the rear.

Other types of UHF antennas commonly employed are: the yagi, Figure 33; the rhombic, Figure 34; and the stacked V, Figure 35, all types which have been described earlier in this lesson.

To increase the gain of the UHF antenna in areas of weak signal strength, several collectors are stacked, and the entire array made properly directive with a large sheet reflector as shown in Figures 36 and 37. In these models, the collectors are bow-tie elements constructed of rods instead of flat metal triangles. As an example of the gain obtained by this method, Figure 38 shows a curve of the gain of the assembly of Figure 37 over the range of channels from 14 to 83.

VHF/UHF RECEPTION

Television receivers designed for reception of both VHF and UHF channels contain either one or two "sets" of antenna terminals. One set is used in the receivers in which a UHF strip can be inserted in a turret tuner for reception of the UHF signals. Where the receiver contains a tuner for VHF and another for UHF, each tuner has its own set of antenna terminals.

The usual arrangement employed for signal pick up consists of one antenna for the VHF channels, and another for the UHF channels. When signal strengths and other reception conditions so require, each antenna is located and oriented for best collection of the channels for which it is designed. From each antenna, a transmission line carries the signal to the corresponding input terminals of the receiver, when the latter contains both VHF and UHF terminals. However, in the case of those receivers with only one pair of input terminals, a method of connecting both lines to the receiver tuner must be employed which will prevent interaction between the two antenna systems.

One method available is the use of a switch which connects either one or the other transmission line to the receiver input. A disadvantage is that this extra switch must be operated every time it is desired to change from a channel in one band to a channel in the other band.

In a second method, both transmission lines are connected to a separation filter, the output of which connects to the receiver. The filter attenuates VHF signals picked up by the UHF antenna, and attenuates UHF signals picked up by the VHF antenna. However, each section of the filter also causes some loss of the signals it is designed to pass. This signal loss in the filter is particularly great in the case of the UHF range. Whether this loss is of great importance depends upon the signal strengths in a given receiving location. Where signals are weak, this type of filter is a disadvantage.

Satisfactory operation without a separation filter can be obtained by employing a UHF converter in the same manner as with receivers designed for VHF reception only. In this case, the UHF turret strips are not used. The converter output is in one of the unused VHF channels. This arrangement is more costly, requires tuning and switching the converter, and incurs a viewer's natural objection to an additional unit placed on top of the television receiver cabinet.

A fourth method is provided by the antenna design illustrated in Figures 39 and 40. This system employs two antennas, one for VHF and one for UHF, connected to a common transmission line. The line carries signals from both antennas directly to the single set of receiver input terminals. In this design, the VHF antenna is a combination of the conical and V types, which is three half-wavelengths long at the VHF high band carrier frequencies. Its directivity and gain are improved by the addition of the reflector. As indicated the UHF antenna is a rhombic, each leg of which is several wavelengths long at the carrier frequencies in the UHF band.

To prevent interaction, a nearly lossless filter is inserted between each antenna and the feed point. A transmission line section presents high impedance to UHF signals picked up by the conical-V antenna. However, at the frequencies of the VHF carriers, this same length of transmission line is only a small fraction of a wavelength long. Its only effect here is to act as an extension of the down lead, and it thus allows unimpeded passage of the VHF signals to the feed point.

Two capacitors form the filter in the UHF antenna section. The capacitance values are selected such that very little reactance is offered to UHF signals, but very high reactance is presented to VHF signals picked up by the rhombic. As a result, only the UHF signals received by the UHF antenna are fed to the transmission line, while only the VHF signals picked up by the VHF antenna are fed to the transmission line. This arrangement eliminates the need for two transmission lines, and the filter between the lines and receiver input.

Although relatively simple in mechanical construction and appearance, the transmission line used as the lead-in is a very important part of the antenna system. Any signal lost by the line reduces the efficiency of the system. As explained in the following lesson, every type of line attenuates the signal to some extent. Thus, this important link may be thought of as a necessary evil, since the energy picked up by the antenna is of no use unless it is carried to the receiver.

* * *

IMPORTANT DEFINITIONS

ARRAY—An antenna containing two or more elements.

DIPOLE—An antenna element consisting of two conductors arranged end to end, with their inner ends connected to the transmission line.

DIRECTIVITY—The ability of an antenna to receive signals in one or more given directions compared with its reception in other directions.

FRONT-TO-BACK RATIO—The ratio of the sensitivity of an antenna to signals arriving from the front to the sensitivity to signals arriving from the back.

GAIN—The signal gathering ability of a given antenna, at a specified frequency, compared with that of a half-wave folded dipole cut for the same frequency.

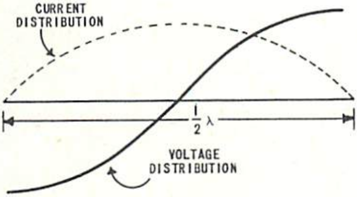


FIGURE 1

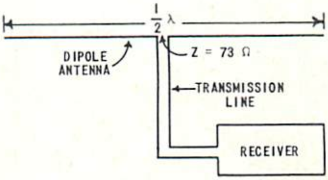


FIGURE 2

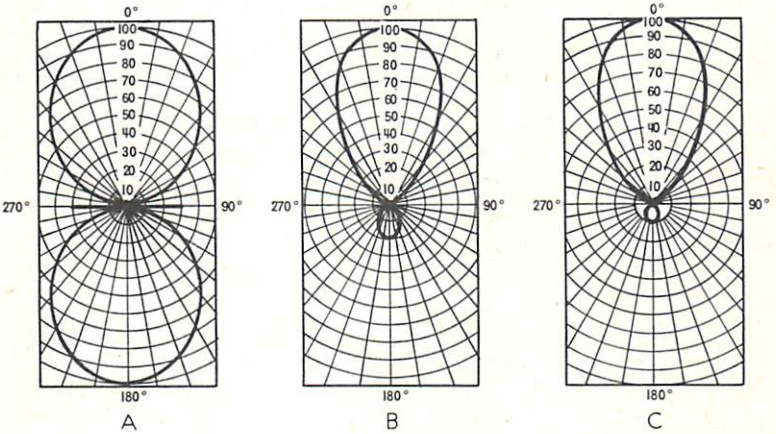
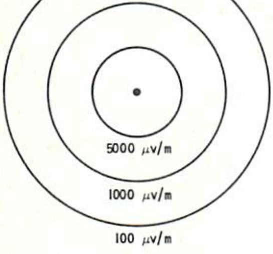


FIGURE 3



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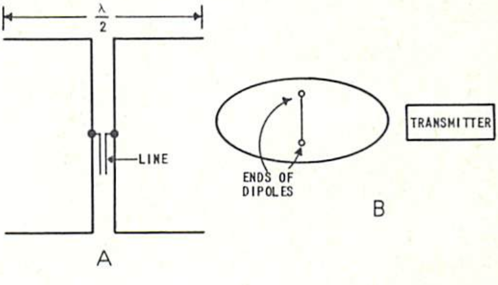
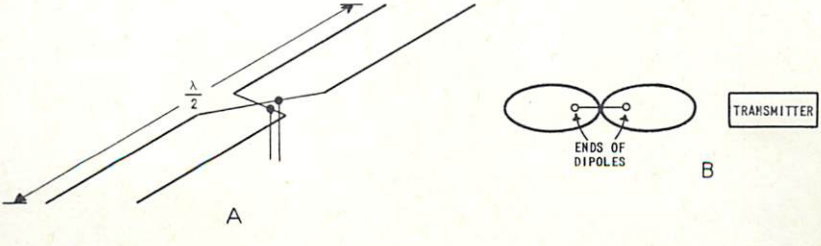


FIGURE 5



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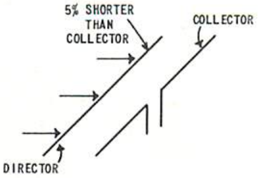

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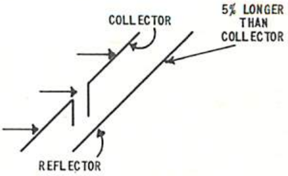

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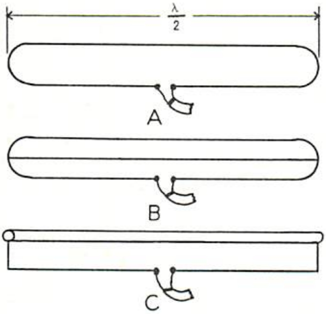

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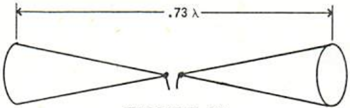
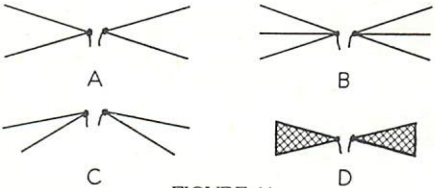


FIGURE 10



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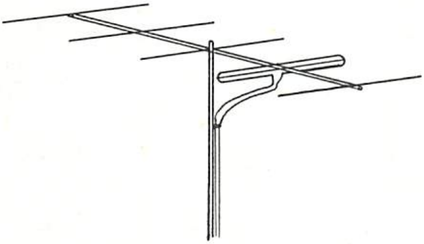

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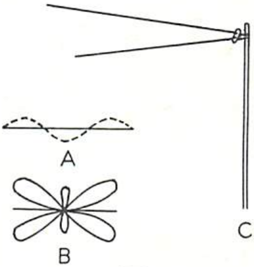


FIGURE 13

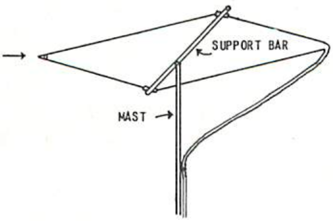
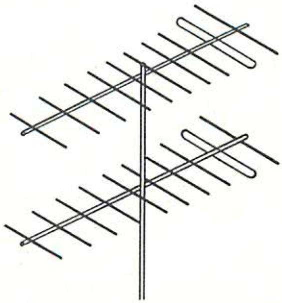


FIGURE 14



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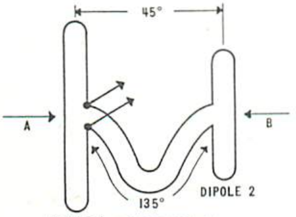

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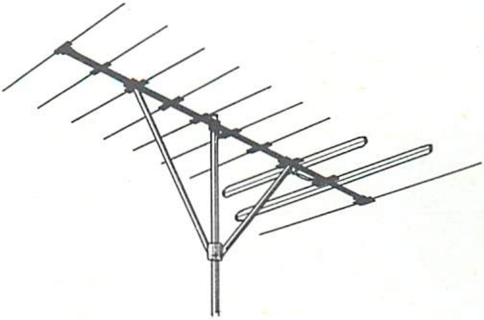

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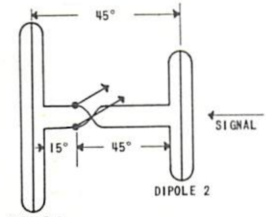

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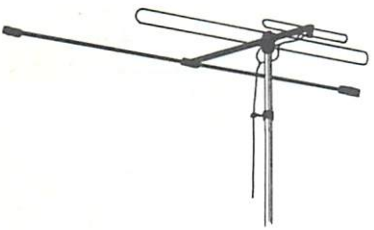

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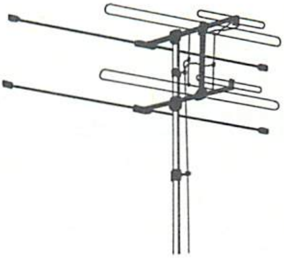

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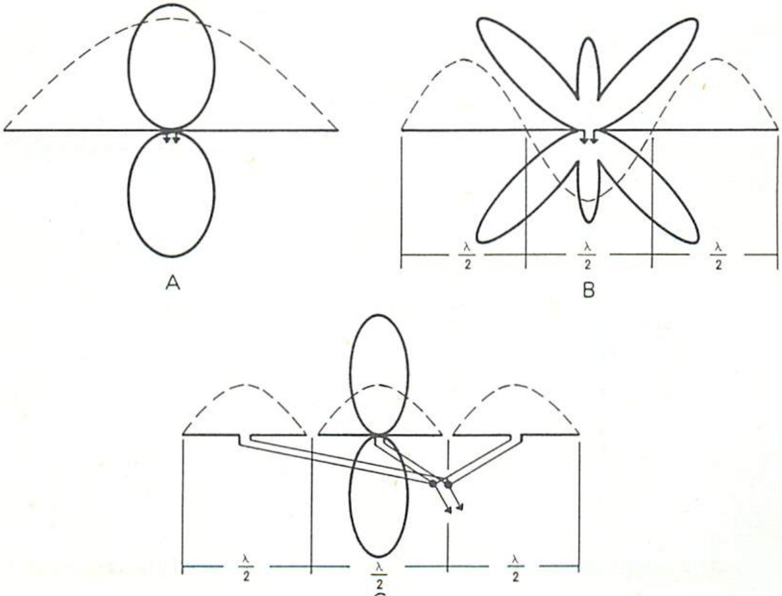

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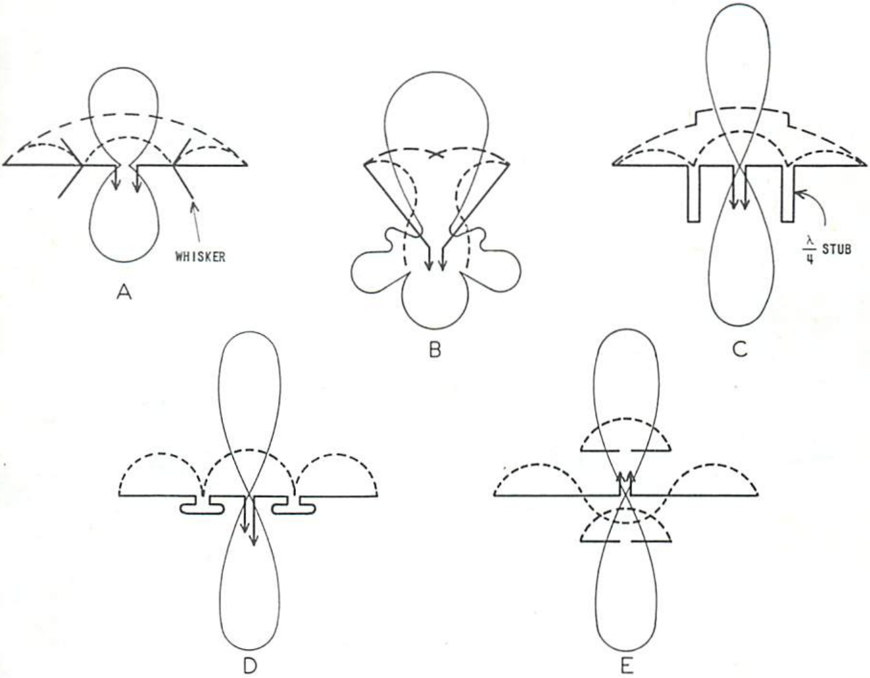

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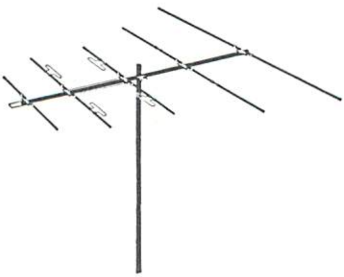

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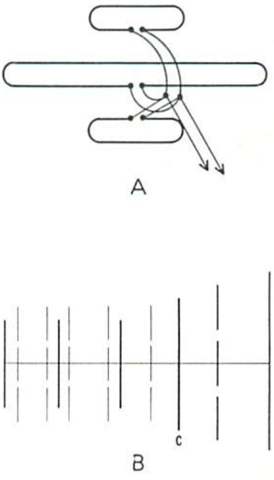

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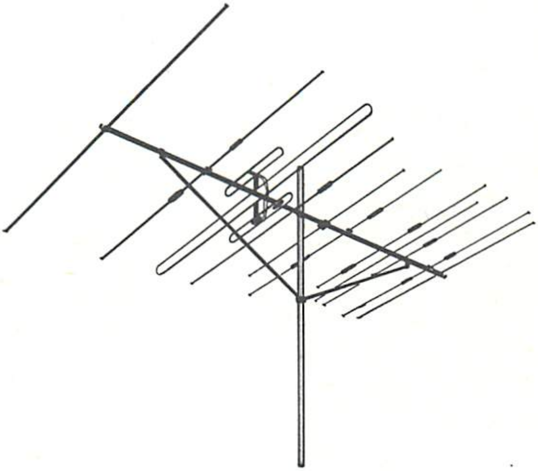

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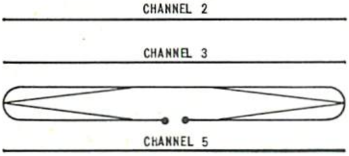

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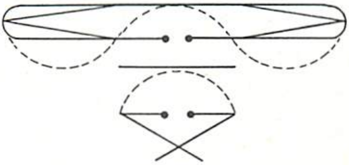

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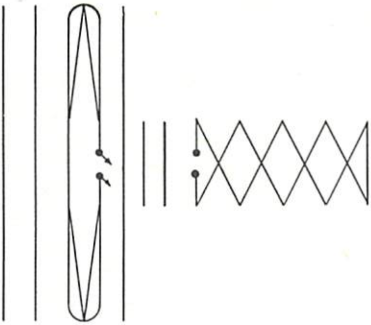

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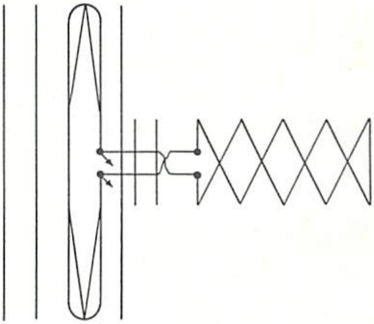

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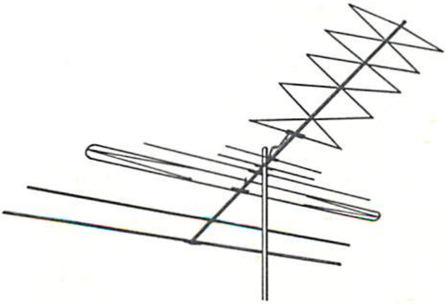
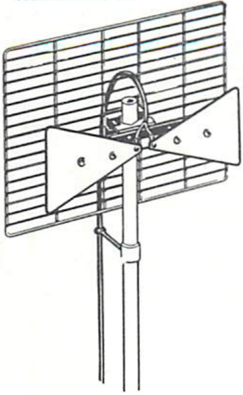
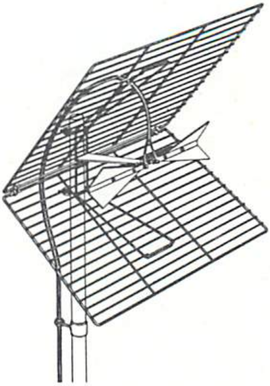


FIGURE 30



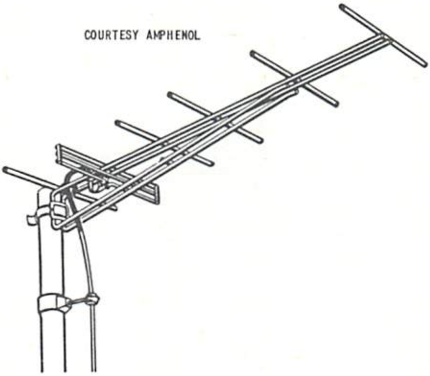
COURTESY AMPHENOL

FIGURE 31



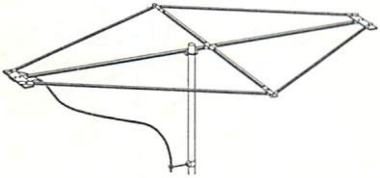
COURTESY AMPHENOL

FIGURE 32



COURTESY AMPHENOL

FIGURE 33



COURTESY AMPHENOL

FIGURE 34

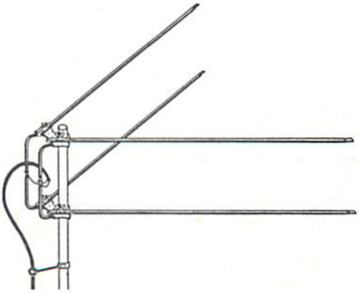


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FIGURE 35

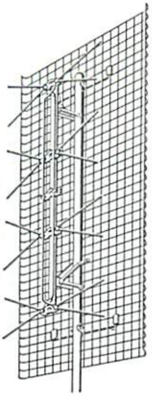


FIGURE 36

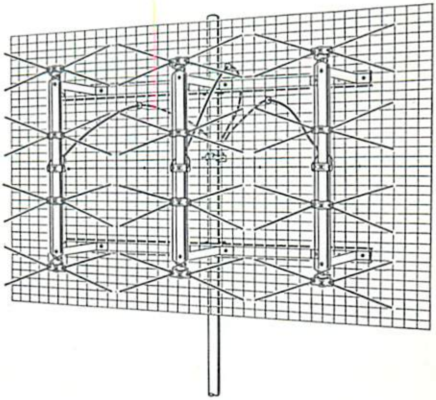


FIGURE 37

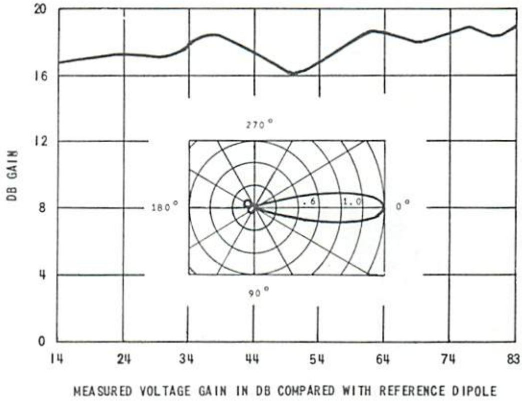
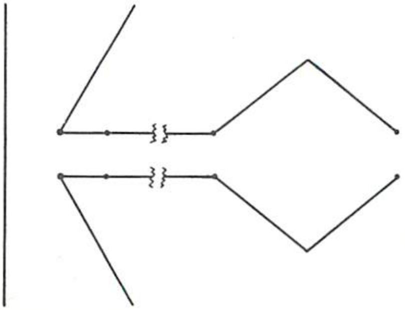


FIGURE 38



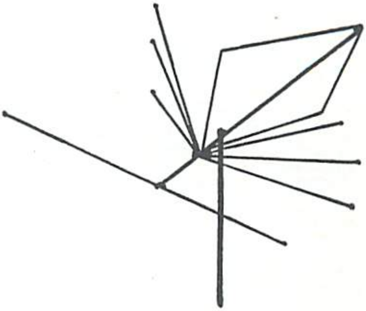


FIGURE 39

FIGURE 40

FROM OUR *Director's* NOTEBOOK

THE MAN WHO FAILS

The man who fails is the sort of chap
Who is always looking around for a snap;
Who neglects his work to regard the clock;
Who never misses a chance to knock.
He is grouchy and slow when work begins,
When it's time to quit, he jokes and grins;
He's always as busy as busy can be.
When he thinks the boss is around to see.
He believes that a "pull" is the only way
By which he can ever draw bigger pay;
And he sulks and growls when he sees his plan
Upset by the "push" of another man.
He's on the job when he draws his pay;
That done, he soldiers his time away,
While the men who tackle their jobs with vim
Keep pushing and climbing ahead of him.
For the man who fails has himself to blame
If he wastes his chances and misses his aim;
He'd win if he'd used his hands and wits;
The man who fails is the man who quits.
—Charles R. Barrett

Yours for success,

W. C. De Vry
DIRECTOR

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